The signs printed with the departures on page 202 are really those appropriate to the reduction of any given hourly mean to the daily mean pressure, and the word *reduction* should be substituted for *departure* in the diagram on page 201. By interchanging the plus and minus signs, departures are converted into reductions, or vice versa. The figures in the present table are departures properly so-called and *not* reductions.—ED.

TORNADO OBSERVATIONS.

By A. H. GALE, Voluntary Observer at Bassett, Rock County, Nebr., dated July 28, 1899.

Wednesday, July 5, the adjoining county of Brown was visited by a tornado at 5:20 p. m., central time. The wind during the day at this station (Bassett, latitude 42° 36′ longitude 99° 55′ west) was southwest, strong in the a. m. and light in the p. m.; humidity high. Temperature 77° at 9 a. m., 90° at 2 p. m. Visited path of storm on 7th and rode over track, interviewing persons near by who witnessed it and also suffered.

Mr. A. Brown, 5½ miles northwest of Johnstown, saw it form; was at work in his barnyard, noticed it coming across his field as a light summer whirlwind such as is noticed on any still hot day. Air at the time was calm. Mr. Brown says he was harnessing a horse at the time, and as the light whirl passed him it gently lifted the straw edges of the roof of his cow shed, but had not enough strength to lift his hat, and passed on. At this point it was devoid of any color, and was mainly noticed by the whirl it made among the grass, straw, and chaff on the ground; he watched its onward movement indifferently, and soon saw it gather a color which made it definable. He then paid close attention to it and noticed it becoming black, angry, and gyrating vigorously, chips, straws, and dirt fell into it, and were absorbed by it and a smoky veil began to envelop the whirling column as it mounted upward. At the same time a funnel began to lower itself from a turbulent low-hanging cloud of an area of about forty acres; the column and funnel soon connected and with this union the "thing" took on a terrifying aspect; up to this time he had no feeling of apprehension. When the whirl passed him he said he was aware of its passage only by its action on the ground. No color. A black cloud above, in commotion, followed the whirl on the ground, which latter was eight or ten feet in diameter. This cloud was alone, separate, and clear from a higher strata of storm clouds above. When passing his point, and as long as within his line of view, he estimated the speed as 10 miles per hour, line of path east by south. I will say here that the entire path from start to end was 18 to 19 miles, and in that distance it made a southing from a due east course of 2¾ miles, and ranged from 1 to 3 rods in width. Two and one-half miles from Mr. Brown's point it crossed a large cornfield and here it received much coloring matter. That the affair was at this time in comfortable order was demonstrated by the shock it gave the first house it struck as it left the cornfield, Mr. John Strohm's. Mr. Strohm and his family saw it as it rose along the slant of the cornfield to his house on its edge, and dove for the cellar. The destruction at this place was complete; house of heavy logs, windmill and tower, and stable, in all seven buildings, completely leveled to the ground, fences upset, broken down. Fence wire woven and interwoven with broken up lumber, straw, débris of all sorts, plastered with mud. Every fence post standing in the track formed a dam around which was massed débris of everything imaginable, the whole daubed with mud; it was a picture of desolation and ruin—dismal in the extreme.

The storm struck the plantation from the west and its main track runs to the east by north down through a "draw" in which most of the trash lodged. Evidently the spout struck the place with its front face, and was not over 30 feet wide at contact. A twinebinder machine 20 feet to south of house was undisturbed. From this place the path of the vortex or storm tube was southeast by east to the place of William Lockmiller, 2½ miles. His house, a frame with an addition, neatly and strongly constructed, on brick foundation, was slid off of underpinning 10 feet to east and 5 feet to north, the two chimneys torn off, the bricks thrown to the east, two strips of shingles with the porch roof on west side of house torn off, all the shingles on east and north side have one corner broken off as one would break off the corner of the cover of a book; the roof being painted red, the broken corners showing the white wood in contrast, gave this roof a singular appearance. The barn, 50 feet south of the house, was also slid over its underpinning square to the east, but not otherwise disturbed. It was at this house that Mrs. Lockmiller was killed. She was in the cellar under the house with the children, and becoming anxious for a boy who was in the barn, started out to call him to safety, when the blast reached the house and, shoving it from the foundation, caught her coming up the cellar steps between the sills and cellar walls, crushing her to death. Had the family remained either in the house or cellar quietly, no one would have been injured. The fan and wheel of the windmill, 40 feet to the east of the house, were carried away, the tower left undisturbed. It is evident the vortex passed close to the north side of the house, as its track through the garden closely adjoining is clearly defined, and the movement of the house and barn and the observed damage were clearly caused by the inward rush of air toward the center of the whirl; shingles on roof, mud spatters, etc., clearly show this. A similar condition and effect were noted at a school house further on near end of path. Direction of vortex path at this point east-southeast.

De Long's place, next in the path of the storm, 2½ miles north of Ainsworth, is a total ruin. The house, a strong one of hewn logs, stables, windmill, and outbuildings went to general ruin. Main part of débris at this place went to the southeast, the house appeared to have been lifted clear off site and strewn over the prairie to the southeast; part of the roof was carried due north and parts to the west; the northeast quadrant shows but little débris. Mr. De Long and family were in the cellar when the house lifted. At this place direction of path was southeast for one-half mile from the house, then its course was due east. No hail or rain fell until after passing, and then both occurred. De Long says while in the cellar the house appeared to be lifted bodily, with strong upward suction (Strohm says he did not notice any upward draft), so much so that he cautioned his wife to hold hard to the children, fearing the upward pull might draw them out of the cellar. His dog was in the house and went away with it, and after the storm passed he came back from across the fields to the westward.

Mr. Trotter's place, about four miles east of De Long's, was the next place in the path of the storm destroyed. Here the destruction was complete. Most of the débris from this house (of frame construction) was thrown to the south and east, a small portion to the north and west; a trail of dish closet furniture described a section of a circle in above direction; the full circle about 4 rods in diameter. A portion of roof landed 250 yards toward the southwest, nearly at right angles to track, and smashed into kindling. Boards, sticks, etc., scattered about pointing lengthwise and from center of disturbance. A hay-covered stable and a straw field, 300 feet east of the house, by a small pool of water, were uninjured. Vortex appeared to catch the house on northwest corner. Observers state that they saw this house rise bodily into the air, whirl about in the funnel, and explode or melt into fragments. The appearance of the ruins indicates this to have occurred.

Here the track of the vortex was from the northwest to the southeast and, after crossing the road just at hand, turned due east, crossing corn field, wheat land, and a stretch of prairie. Next, meeting a couple of empty houses, one a strong log structure, it completely destroyed them. The vortex or funnel at this place apparently left its general easterly path, made a loup to north, taking in the two buildings mentioned and scattering them to the south. Evidently only the edge of the vortex struck these buildings and threw or drew them into the whirl. At this place, and across country from Trotter's place, the track, as marked on grass and fields, was not over 16 feet in width. Here, as at the other points, I observed that most of the débris fell in the vicinity of place of destruction. Between these places there is no débris, and the path is only marked by flattened grass and occasionally turf torn up; all grass in track of vortex lays regularly in line with path of storm to the east.

From this point the storm followed a nearly southeast path, passing to the south of a schoolhouse 150 feet west of its path. This latter was of special interest in demonstrating the force of the indraw or suction of the outside air toward the vortex. The brick chimney on this house was free to the southwest, toward the whirl; the shingles on the north side of the roof were ripped up and carried over the ridgepole toward the vortex. The long axis of the house stood parallel with the storm path, and it is noticed that on the south side, facing the path, the shingles were not disturbed; otherwise this building was not damaged. A Mr. Lehu, who lives near by—just to the east, and north of the path about 40 rods—says the trees of his grove at his house while the vortex passed leaned to the ground to the south; he says a strong indraw was unmistakable. At Mr. Brown's house, 400 yards from path of storm, a heavy farm wagon was turned around and upset toward the vortex. Further on Mr. Layne noted the strong indraw or suction, and his house and barn give their testimony in support; his house lay to the south of the path, and everything about his place that was movable started for the center of the storm, passing through his wheat field, 200 feet away; his house was moved to the north 4 or 5 inches. This was the last damage done. About one mile farther on the tornado died away.

A very interesting talk was had with Mr. W. E. Jerome, living 4½ miles from Long Pine, who observed the breaking up in his pasture, after having injured 20 rods of the pasture fences. He says "the funnel came to a stand, wavered, spread out, lost color and motion, and collapsed with a fall of light rubbish and loose trash, immediately followed by sharp hail; I think the hail broke it up." He estimated the funnel to be, from earth to cloud, 500 feet in length, and the tornado cloud about 80 acres in area and "detached from the cloud stratum above, which was loaded with hail." The noise he heard was a swishing sound, and it is noticeable that Mr. Jerome is the only one conversed with who speaks of any noise. The wind was from the northwest. The rain and hail, after the tornado broke up, came from the northeast, the point the funnel was heading for when it collapsed. It approached his land from the northwest by north, swinging out to the northeast and dissolving.

John Strohm seconds the statement of Mr. Brown by saying that the whirl on the ground ran for some time and did no damage, and did not appear at all dangerous till it made connection with the downward projection from the cloud above, which latter appeared to him to be about 500 feet above ground. Conservative and cool-headed observers interviewed on this point agree, in general, with these gentlemen as to the elevation of these tornado clouds.

A careful summing up of the testimony points to the conclusion that at its beginning this twister was a very simple affair, and in character like a summer dust whirl so often noticed on a still hot day in August, and impotent for harm if it went no farther. It is only when a great condensation is going on above and clouds are forming rapidly that it can take on the features of a destructive tornado, and this brings us to the study of the union of the descending point with the ascending ground whirl. The cloud point, or down-pointing funnel, like the letter V, is black, dense, and compact, while the ascending ground whirl is, comparatively speaking, void of color. I will advance a theory that may account for this. It is not possible, under the general laws of air movement, to imagine a cone of whirling air starting from the ground, gradually mounting upward from a base of 10 feet or so, and not enlarging as its volume increases, or that between the apex of this cone and the point hanging from the cloud above there is a stratum of still or dead air. It is hard to grasp such a state of affairs as this. The belief is strong in my mind that, although not visible, this ground whirl extends upward to the tornado cloud, and is entangled in it and gets its motion from it. At the ground there is no motion of the air which would start it. The ground whirl, as noticed in this present case, had a very thin edge, 5 or 6 inches, like the tire of a cart wheel or the rim of a saucer, in short a simple ring of circling air. This ring extends up to the cloud and is colorless. It envelops the cold point hanging down from above, and which is making an effort to descend to earth down the center of the hot air shaft surrounding it. Several attempts (as in this case) are made before a satisfactory adjustment of the two forces, heat and cold, in the descending core and ascending ring is effected. Until this is done nothing remarkably violent occurs, and up to this point no especial energy is apparent. When, however, the superior energy of the descending core intermingles with the moderately moving ascending rim, and both merge into a perfect whole, then the tornado is ready for business, and proceeds at once to wipe up the earth. The quick change in color of the whole gyrating mass that then occurs is strong evidence of the value of this theory. This color partakes largely of the character of the soil that is swept upward and incorporated with the mass. Were the "spout" dependent alone on water, it would not be as densely black as it is. This present tornado changed color with the ground over which it passed. The tremendous agitation did not produce the electrical discharges one might expect, but one person observed any flash, and then but one. It was observed that the tendency of the tornado was to quickly empty itself of trash picked up, and but the very lightest material remained long afloat. The circular movement of the vortex or spout was counter clockwise, being from north to west to south to east around to north. While the circular motion was clearly established, the appearance of the débris might raise doubts, on a superficial view, but when it is remembered that what was left on the ground had received the last crack of the twister the doubt disappears. In the 18 or 19 miles traveled, the time noted from this station (Bassett) to the end, 20 to 25 miles away, was about 40 minutes, but near by observers set the time 60 minutes, which must be accepted as nearer right.

The width of path at no place exceeded 33 feet, and often it narrowed to 16.

In the matter of suction, or indraw, from the surrounding air, at times it was strongly noted, at other points hardly perceptible. At Mr. Trotter's house, for instance, persons in storm caves did not feel it; on the other hand, a man staying out of his cave a little too long, was hardly able to get to the entrance. The indraw seemed stronger far away than close to.

Up to this time this section of Nebraska has escaped visitations from these terrors, all resting in the belief we were too far west and too near the mountains. It is needless to

say that that opinion no longer prevails, and among the requirements hereafter of a well-appointed establishment will be a properly constructed storm cave.

THE FORCE OF A TORNADO.[1]

By B. F. GROAT, Instructor in Mechanics, School of Mines, University of Minnesota. Dated, Minneapolis, July 24, 1899.

About forty hours after the recent tornado of June 12, at New Richmond, Wis., the writer and Mr. Peter Christianson, also of the University of Minnesota, visited the scene of the disaster.

At Boardman, Wis., about five miles from New Richmond, on the line of the Chicago, St. Paul, and Omaha Railway, we were much interested in two railroad switch targets, the rods of which, apparently owing to the great wind pressure on the surface of the targets, had become bent at an angle which from the train carrying us by we estimated at from 30° to 40° from the vertical. We endeavored to secure these rods from the railroad company in order that we might test the tensile strength of the rods and measure the angle of bending by which we might arrive at the average wind pressure on the vanes, but before Mr. W. A. Scott, General Manager of the railroad could get word to his men, considerable time having been unavoidably lost, the rods had been straightened Mr. Scott, however, very kindly furnished us with the most important dimensions of the targets, from which we have made a calculation that we think may interest the Weather Bureau; at least we believed others would like to know that two rods of the dimensions shown on the accompanying sketch (omitted) had been bent, as we suppose, by the force of the wind.

The exposure of the switch target to the wind is shown by an accompanying sketch (omitted.) A round vertical iron rod, 1⅜ inch thick, supports vertically a feather-shaped iron plate that is 30 inches long and 13 inches broad.

The following is a brief outline of what we observed and our calculation: The two targets were apparently struck nearly normal to their surfaces by the wind. We had no opportunity to make a survey of the ground, although as we passed by we saw no evidence that the targets had been struck by flying débris of any consequence, but, of course, there is a chance that this may have been the case. As we could not learn the exact value of the angle of bend, we did not think the data sufficient to warrant a test of the tensile strength of the rods, but merely assumed a probable value, and from that and the dimensions of the target, calculated the average pressure per square foot of surface of the vane necessary to bring the bending moment of the rod to the point of straining.

The center of gravity of the surface exposed to the wind is about 36 inches along the central line of the rod above the bend. The area of the target, including that portion of rod above bend, is about 343 square inches. The rod at bend is 1⅜ inches in diameter.

Assuming that the rod has a tensile strength of 30,000 pounds per square inch at elastic limit, which serves approximately either for wrought iron or soft steel, it is easy to show by the ordinary rules of mechanics, that the average pressure must have been at least 90 pounds per square foot of area normal to the wind, provided our assumptions are correct. If we use for the relation between pressure and velocity the formula $P = 0.005\ V^2$, we arrive at 134 miles per hour. Of course, to bend the rods to the angle mentioned would require considerable more pressure, but probably not enough to render it improbable that the rods were bent by the unaided force of the wind, especially when it is remembered that the tensile strength may be less than assumed. See line 16 from top of page 54, "Report of Board of Engineer Officers as to the maximum span practicable for suspension bridges," published by the War Department for a similar calculation in connection with the tornado that crossed the Champ de Mars.

[1] In submitting the accompanying article, Mr. B. F. Groat desires that attention be called to the fact that there is a possibility that the switch targets mentioned by him were struck by some heavy piece of flying material and not bent by the force of the wind only. On this point, he says he could not secure absolute evidence, but, from all that could be learned, he was led to believe that the targets were bent by the unaided force of the wind. Mr. W. A. Scott, General Manager of the Chicago, St. Paul, Minneapolis, and Omaha Railway made every endeavor to secure all desired information, even ordering the targets and rods taken out and shipped to him by express, for which courtesy Mr. Groat desires to make full acknowledgement.—ED.

SUDDEN OSCILLATIONS IN LAKE LEVEL—PRESSURE WAVES.

By ALFRED J. HENRY, Chief of Division.

[Extract from Lake Chart, September, 1899.]

A so-called tidal wave swept southwestward over Chequamegon Bay on the morning of July 22, 1899. The water of the bay rose suddenly about 3 feet above the normal stage, flooding a number of docks in Ashland, Wis., at the head of the bay, and causing several mills to shut down temporarily. At 11:30 a. m., the water began to recede, and by 3 p. m. it was slightly below normal. A second rise occurred about 4 p. m., and minor oscillations were noticed until the waters assumed their normal level. The wind was from the south and the weather fair.

Sudden waves and swells in tranquil weather have been noted on the Great Lakes, and commented upon from the earliest historic times. These sudden oscillations have never been, so far as known, of sufficient amplitude to seriously injure a vessel on the open lake. They may easily, however, be the cause of considerable damage in narrow channels, and especially in harbors where the shore lines converge to a point, as in the case of Ashland, thereby greatly increasing the size and destructiveness of the wave.

In April, 1893, a somewhat similar wave swept over the southern portion of Lake Michigan, causing a rise of the water in the harbors of about 4 feet.[1] Considerable damage was done to vessels anchored in the Chicago River and ports along the southeastern shore of Lake Michigan. The question was then asked, can these waves or *seiches*, as they are sometimes called, be predicted a few hours in advance of their coming?

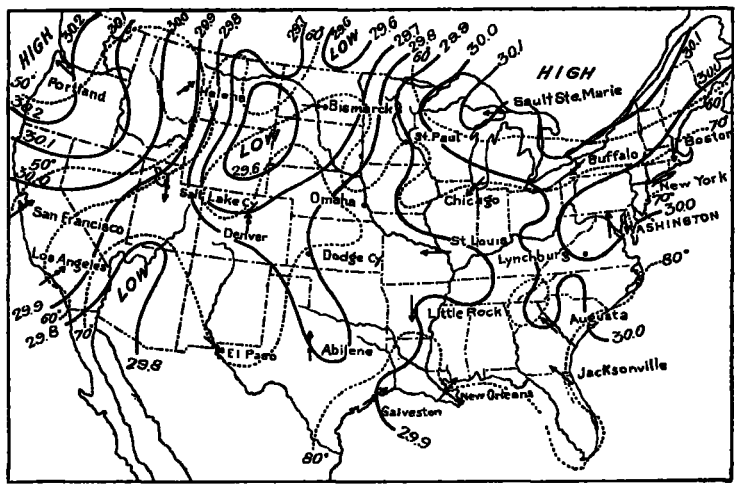

Fig. 4.—Pressure, temperature, and wind direction, 8 a. m. July 22, 1899 (75th meridian time).

The wave in Chequamegon Bay occurred at a time when the local weather conditions gave no sign of unusual disturbance. The daily weather map, however, shows that a storm whose influence extended over the region in question, was passing eastward north of the international boundary line. [See Fig. 4.] Light rain had fallen at Duluth and Port Arthur, but it is not known whether or not rain fell at Ashland.

The occurrence of sudden changes in the levels of lakes has been

[1] See Marine Record, April 13, 1893, American Meteorological Journal, October, 1893.